WHITE PAPER

Key performance indicators in product development

Systematically evaluate and continuously improve innovation productivity

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CONTACT Software

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Preface

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The continuous improvement of (business) processes and products is crucial to the competitiveness of a company. It is expected that products be developed and improved ever faster and cheaper. That is why KPIs that provide information about a company's innovation productivity have become increasingly important in recent years. These KPIs help decision-makers systematically measure, evaluate and manage products and processes. KPIs can be used to make interrelationships and important information within a company transparent.

A wide variety KPIs have long been collected in departments like the production department with the aim of monitoring the quality of the manufactured components and the performance of the production processes and optimizing them in the context of a continuous improvement process (CIP). Although universally accepted KPIs for evaluating production processes, such as those specified by the German Mechanical Engineering Industry Association (VDMA) (VDMA Standard Sheet 66412-1 MES KPIs) exist, assertions about the effectiveness and efficiency of product development are generally not very reliable.

If development processes are to be managed more efficiently and the effectiveness of the R&D organization improved, meaningful KPIs that identify weak points and potential in the processes are needed. This was the aim of the Process Indicators for Product Engineering (PIPE) initiative launched by the VDMA in cooperation with leading PLM software and service providers such as CONTACT Software, Dassault and IBM. Appropriate KPIs for product development and core processes such as change, project and configuration management are available in a VDMA guideline [1].

This white paper describes the requirements relating to performance indicator management in the product development process and explains the processes and advantages of the continuous and automated collection of KPIs in operative product lifecycle management (PLM) systems.

Challenge

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The ability to develop innovative products is crucial to the competitiveness of a company and at the same time a key driving force behind a more strictly systematic approach to product development. If products are late being launched onto the market or fail to meet cost and quality targets, sales and profit forecasts will not be met.

Not only products but also development processes are becoming increasingly complex. Mechatronic products contain embedded software and systems that are increasingly being connected to other systems or subsystems. Their development not only requires more systematic forms of cooperation between the different engineering disciplines within a company but also with the supply chain over which the development and production of these networked systems are usually distributed.

How can the effectiveness and efficiency of these processes be measured and evaluated reliably?

Although the original data for products, projects and processes is stored in the PLM systems, it has not yet been used or has not yet been used systematically. The reasons for this are a lack of understanding regarding the systematic controlling of development processes and the fear that controlling in R&D could be counterproductive. In recent years, however, there has been an increasing awareness of the fact that a company's own innovation productivity must also be the subject of systematic evaluation and continuous improvement.

> The starting point for project controlling is a meaningful system of key figures.

The starting point for efficient performance indicator management is, on the one hand, establishing a coherent performance measurement system, i.e. a manageable and coordinated KPI portfolio whose elements are organized in an overall context. Crucial in this context is the relevance of the individual KPIs as this ensures that irrelevant KPIs and information are ignored. On the other hand, it must be possible to continuously collect and consolidate KPIs from operative processes and systems automatically in order to minimize the amount of time and effort involved in calculation.

Performance indicator management can be defined and integrated into products and processes with the help of a PLM system. A dashboard that automatically displays generated, current and historical product and process data provides companies with comprehensive control and management capabilities.

Performance indicator management

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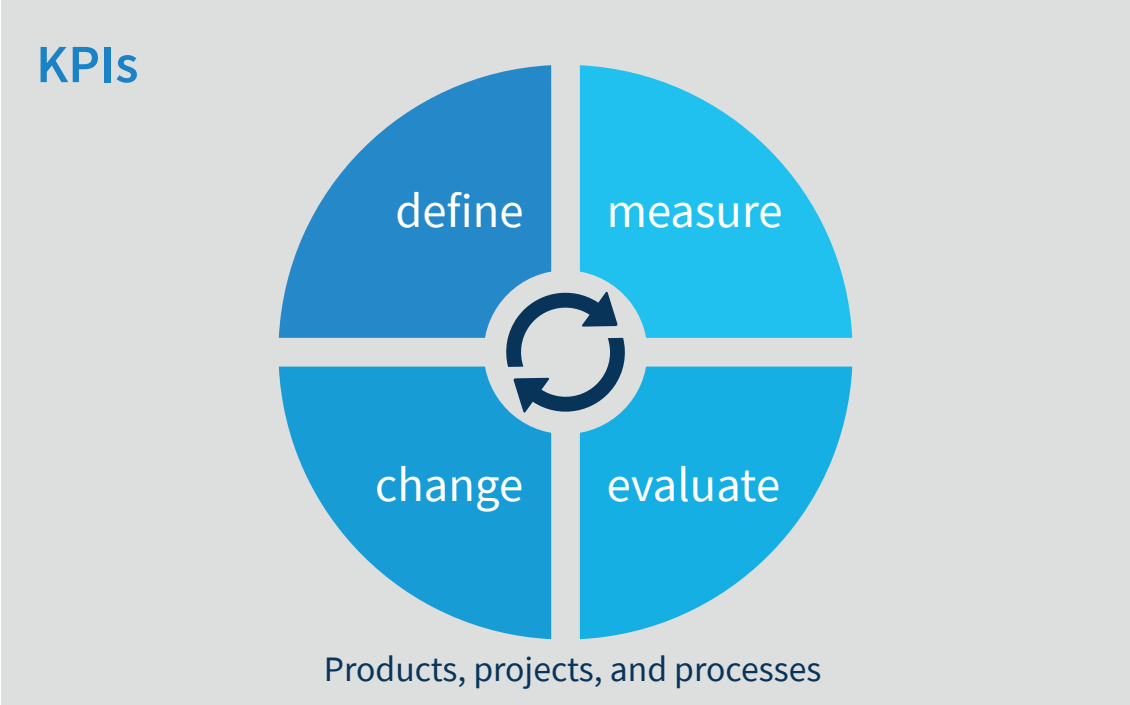

Figure 1:
KPIs and performance indicator management

KPIs are a tool that can be used for controlling and quality assurance purposes. They serve to translate generally formulated corporate objectives or project requirements into concrete or measurable targets, evaluate the results achieved and highlight future developments.

Performance indicator management is crucial to the successful handling of KPIs. It integrates multiple object and process KPIs and provides the following management tools for work performed in this context: define, measure, evaluate and change.
A company must define a product development method before products, projects or processes can be evaluated using KPIs or performance measurement systems.

Product development methods

There is a large number of different product development methods. The selection of a specific method determines the goals and criteria according to which the products will be developed. These in turn determine which KPIs need to be collected. Two different approaches that are particularly relevant to KPIs in product development are presented below.

Time-to-Market (TtM)
If companies use the TtM method, the timing of the market launch is determined before product development starts. The aim of TtM management is to optimize the innovation process in terms of time. This means that innovative products – from the initial idea to market launch – are planned in such a way that they are launched onto the market at the economically optimum time [2].

Design to X
A somewhat more comprehensive approach is provided by design to X (also design for X), which focuses on the product. Measurable attributes or target values such as weight or cost are defined for a product. This assignment makes it possible to monitor the specified targets during development.

If only the cost of a product is measured, this is referred to design to cost. The cost is kept as low as possible and is determined in the early phase of development. Cost-conscious design is becoming increasingly important for the success of a product [3].

Table 1:
Overview of KPIs

KPI	Determination	Sample KPIs
Absolute numbers	Individual numbers, totals, differences and averages	Sales, cost of materials, balance sheet total
Structural numbers (relative numbers)	Partial amount in relation to a total amount	Equity ratio, share of sales
Relation Numbers (relative numbers)	Different variables with a meaningful connection are correlated	Unit costs, return on investment, throughput time, return on sales
Measured Numbers (relative numbers)	Comparison of factually identical but locally or temporally different characteristic values	Sales growth, price development, market growth
Index numbers (relative numbers)	Extension of the concept of measurement figures by examining the development of several variables over time	Price indices, volume indices, value indices

Key performance indicators

KPIs are defined as highly condensed metrics that provide information about a fact that can be expressed in numbers in a more precise, coordinated and documented manner than can be provided by ratios or absolute numbers, provide information about developments within a company and constitute strategic success factors [4]. In most cases, ratios provide information about cause-and-effect correlations or, as indices, illustrate evolution of a value over time. The following table lists different types of KPIs [5]:

When it comes to controlling product development, another type of differentiation, namely between object and process-oriented KPIs, makes sense. While object KPIs support controlling for individual products and projects, process-oriented KPIs form the basis for continuous process improvements [4].

Object KPIs
Object KPIs always describe the attributes of exactly one object: a product or a project. The purpose of product KPIs in the context of design to X and project KPIs for traditional project controlling is to make the handling of routine operational business more efficient.

Product attributes and product-specific targets include costs, weight, installation space, consumption and emissions. For example, the progress of an individual project can be illustrated in the form of an earned-value or milestone trend analysis.

Process KPIs
Process KPIs, on the other hand, describe the attributes of a business process and evaluate the attributes of several objects accordingly. Process KPIs that look at the performance of the organization or certain core processes include, for example, the throughput times for technical changes or adherence to schedules when processing orders. They document average values from a set of individual values, such as the throughput times for all the technical changes within a certain period. In addition, they allow comparisons to be made in order to identify

trends, for example over specific periods of time. Process KPIs make it easier to identify weak points in the processes and thus form the basis for continuous process improvements.

The definition of conclusive process KPIs also provides the basis for determining the maturity of the organization and its business processes. Many companies use the Capability Maturity Model Integration (CMMI) approach to identify potential for rationalization and implement process improvements. CMMI provides a variety of reference models for assessing the processes and the strengths and weaknesses of an organization, including companies that develop software, systems or hardware (CMMI-DEV). These reference models combine the best practices from certain process areas (e.g. project planning, requirements engineering, etc.) but without providing concrete instructions for their implementation [6].

Interpreting KPIs

KPIs provide aggregated information. How this information is interpreted and which conclusions are drawn or forecasts are made will depend on the person analyzing the data[4]. The often high number of impacting factors means that care must be taken when measuring and interpreting key process data in particular. For example, it may be useful to classify technical changes according to product areas and release status (in development, sample/prototype, in series production) in order to draw the correct conclusions about the efficiency of change management from the automatically calculated throughput times.

Performance measurement systems

In many cases, individual KPIs alone do not allow the development of products or the effectiveness of processes to be assessed accurately. Only in combination with other indicators, e.g. as part of a more comprehensive performance measurement system, do they allow further evaluations such as the reasons for success or failure or the potential opportunities and risks of entrepreneurial activity. A performance measurement system refers to a set of variables that are related to each other, complement each other or clarify each other. A distinction is made between one- dimensional and multidimensional performance measurement systems, depending on whether they yield a single monetary KPI or several both monetary and non-monetary KPIs [4].

One-dimensional performance measurement systems

The ROI tree, one of the oldest (one-dimensional) performance measurement systems, was developed by DuPont. Only past monetary values are included in the ROI tree [7].

Multidimensional performance measurement systems

The use of multidimensional performance measurement systems makes it possible to take a holistic approach. Not only financial KPIs such as sales or profit but also actors, processes and values like customer satisfaction are taken into consideration here. Examples of multidimensional performance measurement systems include the Balanced Scorecard (BSC) and Total Quality Management (TQM) approaches.

- **BSC:** Deriving concrete measures and criteria from business practices and quality-related specifications for evaluations poses a challenge for many companies. The BSC approach provides assistance in this context. The BSC is a systematic concept for measuring, documenting and managing concrete activities, such as measures for achieving strategic goals (e.g. reducing development costs), in a company. This involves not only taking a look at the financial aspects but also the customer‘s point of view, such as customer satisfaction, process quality and employee potential as well as long-term prospects for growth. A performance measurement system that is tailored to the organization in question is developed on the basis of critical success factors and a cause-and-effect analysis [8].
- **TQM:** The TQM approach is essentially based on a self-assessment of the organization in which the actors and processes on the one hand and the results on the other are evaluated and correlated with each other [9].

> A key figure system is a set of variables that are objectively related,complement or explain each other.

Interpretation of performance measurement systems

When developing a performance measurement system, proven concepts and methods such as BSC or TQM can serve as guidelines, but ultimately each company must decide for itself which performance indicators have predictive value and should be recorded. If, for example, past experience shows that satisfied customers buy more products, customer satisfaction can be measured and used as an early indicator for sales forecasts. Perhaps, however, there is a much closer correlation between the satisfaction of a company's own employees and sales performance

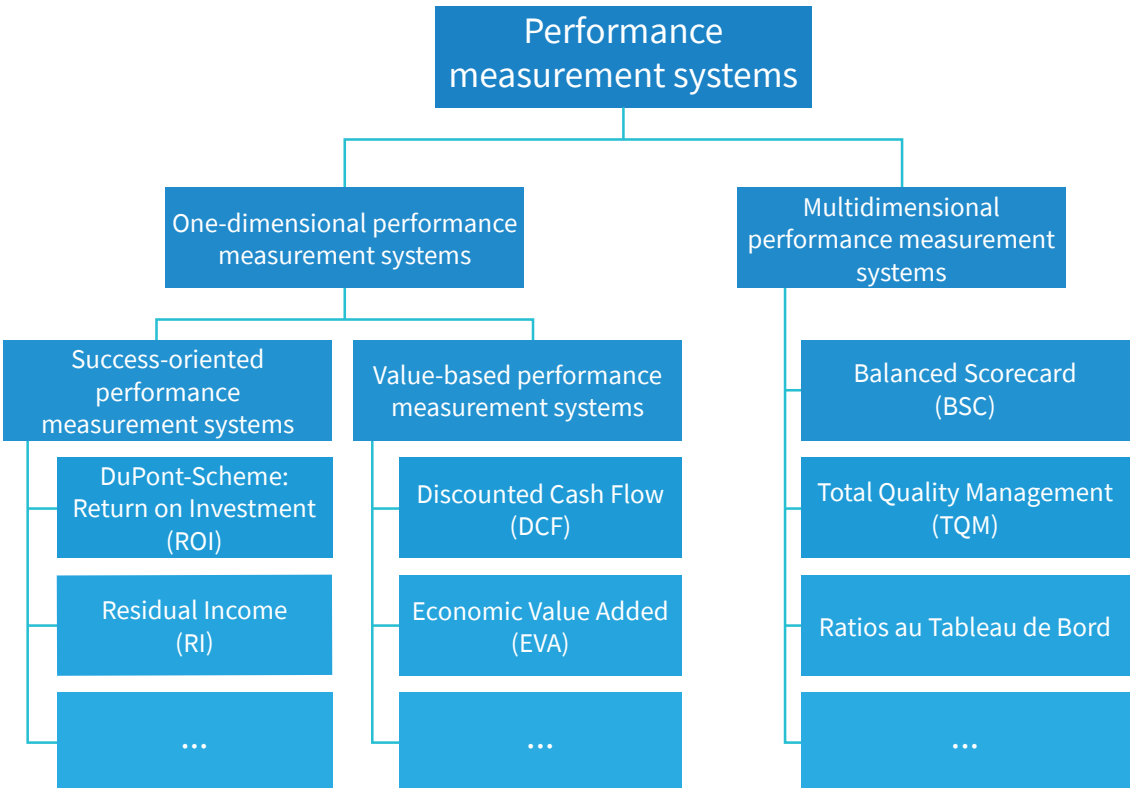

Figure 2:
Overview of performance measurement systems (based on [5])

PLM-integrated performance indicator management

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The development of performance indicator management capability not only determines which KPIs are to be evaluated but also the IT solution that will provide performance indicator management support. The architecture of powerful PLM solutions makes it possible for them to prepare and make available both object-oriented and process-oriented KPIs. This means that they can provide simultaneous support for different performance indicator management applications and create synergies between them, i.e. allow KPIs that have already been determined to be used in different forms for different roles and tasks – from product management to project management and process development through to corporate management.

One particular performance feature of PLM-integrated performance indicator management is the possibility of defining actions if recorded values deviate from the target specifications and to track them in the PLM context. This means that the actions are recorded together with the (estimated) impact on the desired target or target value and the associated costs so that product developers or quality assurance staff can assess, on the basis of a graphical presentation, which combination of actions will enable the target to be achieved at the lowest possible cost. At the same time, the impact of the actions taken are monitored with the aid of automatically recorded KPIs so that additional action can be taken if there is still a gap between target and actual values.

Users are provided with the following management tools (see Figure 1):

1. Define KPIs
2. Measure processes and products using KPIs
3. Display and evaluate information
4. Change or improve processes and products

> A special feature of a PLM integrated key figure management is the possibility to check for deviations from the targets define corrective actions and track them in the PLM context

The integration of performance indicator management, which supports both case-by-case analysis and process analysis, makes certain demands on the architecture of the PLM solution with regard to the definition of object classes and KPI types. Useful in this context is a framework that makes it possible to define KPIs for both objects and object classes, automatically calculate the actual values of KPIs at freely selectable intervals, automatically aggregate actual values via object structures, record their history and define targets for certain KPIs using formulas. In addition, comprehensive performance indicator management requires tools for an appropriate representation of all the elements comprising a KPI and of the full set of KPIs defined and available in the system. It must be able to display all parameter values defined for an object or class together with the associated target values and levels of fulfillment.

Performance indicator management in PLM systems can also be linked to other functional areas such as requirements management, for example to define KPIs for continuous monitoring of critical requirements.

Product-oriented performance indicator management
in the PLM context allows developers to take account of a number of different criteria. Product properties can be evaluated continuously by automatically deriving certain parameters from the CAD system or the calculation tool and aggregating them if necessary (e.g. the weight of the individual parts). Similarly, the KPIs for project controlling can be aggregated at different levels of detail in order to obtain an ongoing view of the current project status.

Process-oriented key indicator management
simplifies the task of identifying potential improvements in the development organization based on KPIs that provide information on the performance of certain core processes such as change, project or configuration management. The corresponding KPIs can be tracked over time. This allows the benefits of certain organizational changes or the introduction of new PLM tools to be assessed.

Integration of external data sources

There is a wide variety of IT solutions for the different application areas within the value chain. Far-sighted, cross-system analysis can only be carried out using a central performance indicator management solution [10].

Production process data is usually generated in manufacturing execution systems (MES) or a combination of MES and ERP systems. In many companies, PLM systems are the most important source of product, project and process-relevant data. Therefore, a central performance indicator management solution should be integrated in the PLM system to improve both the product and the product development process.

In case of product and project KPIs, it is reasonable that the solution should be embedded in the PLM context because the values need to be recorded and analyzed during development and project work.

Integration in the PLM system is, however, even more important when it comes to the process KPIs as they often involve automatically recorded and/or aggregated data. The process data comes from MES or ERP systems and can be transferred to the PLM system and updated automatically via interfaces. This allows interactions to be mapped within a system using KPIs.

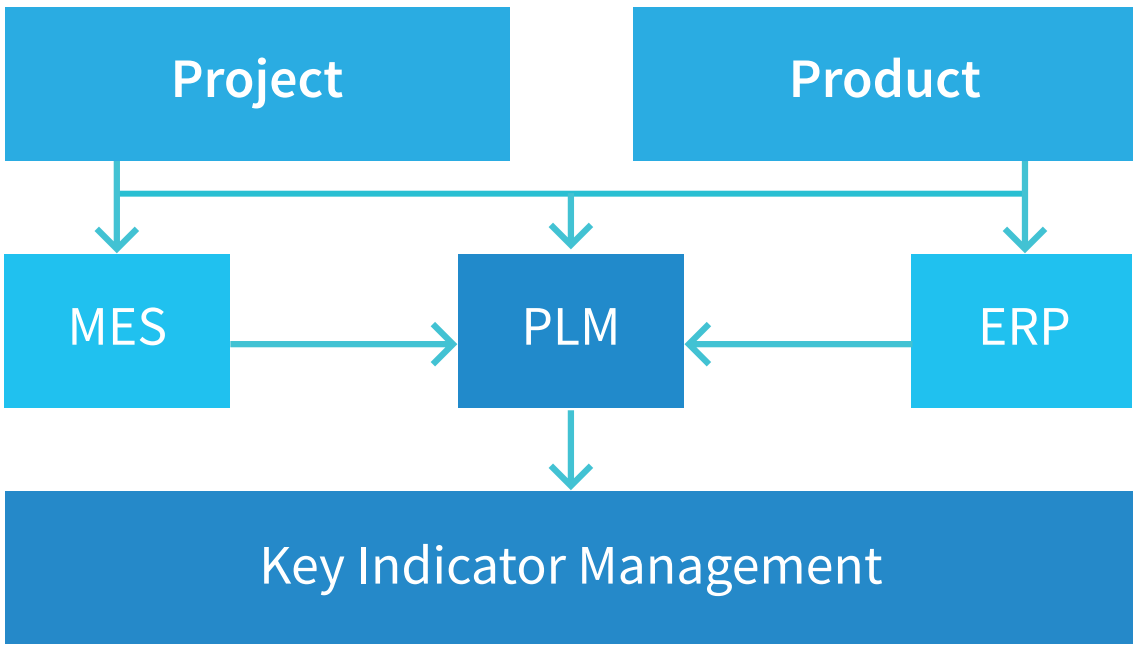

Figure 3: Integration of external data sources for calculating KPIs

CONTACT Metrics & Reporting

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CONTACT Software's Metrics & Reporting module takes a holistic approach to performance indicator management in product development and allows consideration to be given to the relevant objects, i.e. products and projects, as well as processes.

Defining and measuring KPIs

KPIs can be easily defined for any PLM business object (product, project, etc.) and process (ECM, RQM, etc.). Their development can be tracked over time and performance can be improved by taking appropriate action. This enables the user to control and intervene in good time by means of KPIs.
When defining a KPI, users can decide whether the actual KPI values are to be entered manually, whether and how they are to be aggregated automatically using object structures, or whether they are to be calculated automatically by the system. Different options are available where the rules for automatic calculation are concerned. These include logical expressions, SQL statements and Python code. If users obtain important data from other systems such as an ERP system, this data can be imported via an interface and thus evaluated in the PLM system.

Product attributes and target ranges

Once a KPI has been defined, formulas can be used to define discrete or continuous target ranges within which the actual KPI should lie and to monitor their achievement accordingly. The target ranges can be defined for specific product attributes, such as weight or limit values for emissions.

Action management

Another potential application is integrated action management in which actions to be taken in the event of discrepancies in the target ranges are defined. The predicted effect on the achievement of the target and the costs associated with them can be stored here. This allows a comprehensive analysis of which combination of actions will enable the target to be achieved at the lowest possible cost to be performed. The success of the actions can be monitored continuously. This is where values such as material costs, for example, are specified.

Application of object KPIs

Individual objects such as products and projects can be examined.

- **Project controlling:** One project management application is KPI-based controlling, e.g. using earned value KPIs such as planned and actual values or cost and time efficiency.
- **Product tracking:** Another application is product tracking. Here the product is placed on focus (design to X). Attributes such as the weight of a product are defined with target values and monitored during development using target tracking.

Application of process KPIs

One example application for evaluating a process is the implementation of technical changes (engineering change (EC)). The crucial PLM value is the monitoring and improvement of the lead time for individual ECs. KPIs can be used to answer the following questions:

- How many ECs are active?
- How many new ECs are there?
- How many ECs have been rejected?
- How long does it take on average to process an EC?
- How many ECs have been corrected?

Kennzahl	Regel
# active	active = …
# new	New=…
%-set discarded	… total and after ECR, ECO phase in relation to total ECs started and ended in the reference period
Ø throughput time	… activation to completion, total and after ECR, ECO, ECN phase
%-set with correction	… total and after ECR, ECO phase in relation to total ECs started and completed in the reference period

Table 2:
Example Engineering Change

KPI cockpits: visualization, evaluation and reporting

KPI cockpits are intuitive, integrated web applications in which achievement of the target, history and actions defined for the individual KPIs are displayed. The actual KPI values are automatically recorded in the history so that trend recognition is possible for each KPI. Target ranges, actual values and actions can also be entered and edited directly here.
The reporting mechanism provides users with a variety of different display options: display of the evolution of the value over time, evaluation of the relationships between different parameters and the comparison of objects and processes. The key features of the KPI cockpit include

- role and person-specific KPIs,
- visualization of the current extent to which the target has been achieved,
- direct entry of planned target ranges,
- cost fluctuations associated with the actions taken and
- simple sorting and filtering options.

The following figure shows an example of the display of a process-related KPI in the KPI cockpit. The visual display of the KPI cockpit is divided into two parts. At the top, there is a chart showing the development of the KPI over time on the left and a diagram of the measures initiated on the right. The individual KPIs for projects are listed below the process view.

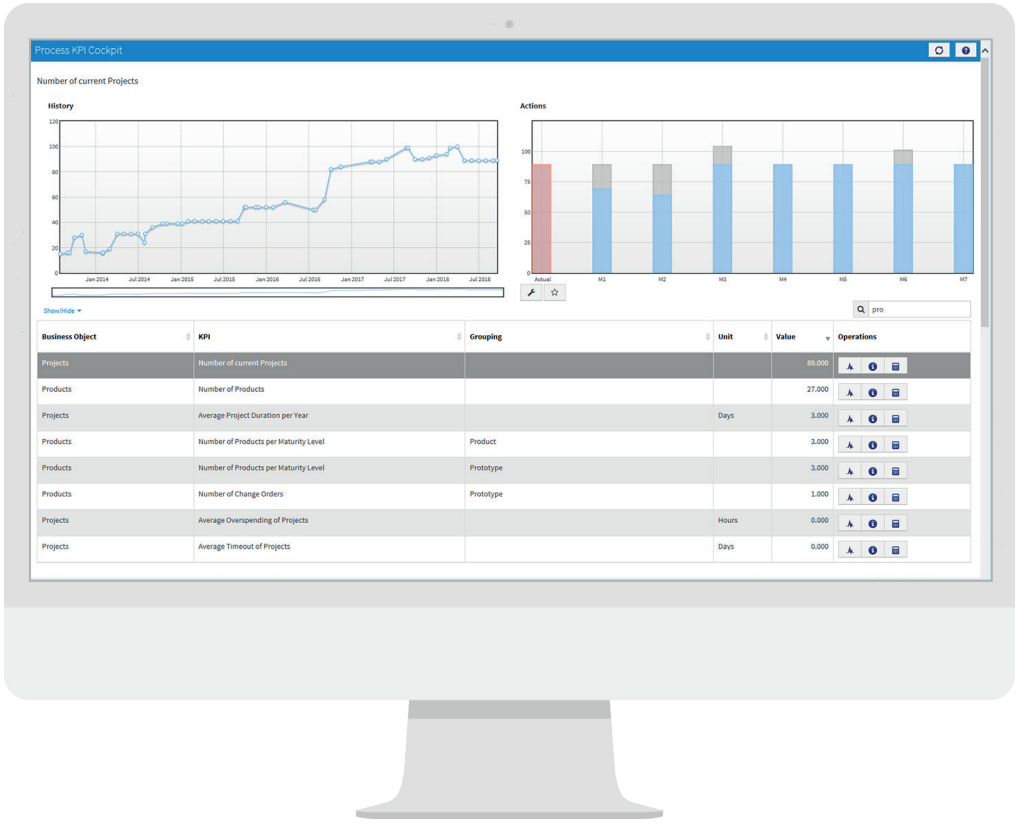

Figure 4:
Example of process KPIs

Summary

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> PLM-integrated key figure management visualization contributes to the as well as dashboard and reporting functions more transparency in the company..

The continuous improvement of (business) processes and products is crucial to the competitiveness of a company. It is expected that products be developed and improved ever faster and cheaper.

The developers and design engineers in companies are facing a host of challenges when it comes to product development. In addition to target costs, they have to comply with increasingly strict statutory requirements regarding safety, environmental compatibility, energy consumption, etc. as they work and they need to clearly document their compliance. The number of critical requirements or product attributes that have to be monitored during development is steadily growing. Compliance management is an integral part of controlling development processes today.

That is why key performance indicators (KPIs) that provide information about a company‘s innovation productivity have become increasingly important in recent years. The processes involved in innovative product development need to be systematically evaluated and controlled. PLM systems offer an IT-based approach and are ideal for making it possible to evaluate and control product development using KPIs. Existing products and processes can be influenced and improved in a targeted manner.

Software applications like Metrics & Reporting from CONTACT Software offer an approach that enables the entire innovation process to be managed and evaluated using defined KPIs.

The key synergy effect of PLM integration is the ability to define uniform procedures that can be controlled centrally for all processes, record critical values automatically and continuously and display them in real time with the help of powerful dashboard and reporting functions. PLM-integrated performance indicator management thus makes a significant contribution to increasing transparency within a company.
The translation of corporate objectives into corresponding metrics and their ultimate evaluation is a matter for the companies themselves and requires employees with the requisite skills.

Glossary

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Balanced Scorecard (BSC)
BSC is a systematic concept for measuring, documenting and controlling concrete activities in the company, such as measures to achieve strategic goals.

Design to X
Design to X is a product development method. Measurable attributes such as weight or cost are defined for a product so that the targets set can be monitored during development.

Key Performance Indicator (KPI)
KPIs are highly condensed metrics that provide information about a fact that can be expressed in numbers in a coordinated and documented manner.

Performance measurement system
A performance measurement system is a set of variables that are related to each other, complement each other or clarify each other.

Performance indicator management
Performance indicator management integrates several object and process KPIs and provides management tools for defining, measuring, evaluating and changing when working in this context

Process Indicators for Product Engineering (PIPE)
PIPE is an initiative launched by the VDMA in cooperation with well-known PLM software and service providers to determine suitable KPIs in product development.

Product Lifecycle Management (PLM)
PLM is a management approach and includes the holistic management of all data and information that is processed and distributed when developing new products or updating existing ones. PLM also includes the ability to control and monitor the process of processing and distribution across companies. A PLM solution results from the interaction of people, working methods, models and IT tools.

Product life cycle
The product life cycle refers to all phases that a product passes through over time.

Time-to-Market
TtM is a method of product development. The aim of TtM management is to optimize the innovation process in terms of time.

Total Quality Management (TQM)
The TQM approach is essentially based on a self-assessment of the organization in which the actors and processes on the one hand and the results on the other are evaluated and correlated. Here, too, the valuation is based on certain KPIs that are collected and aggregated.

List of abbreviations

Abbreviation	Explanation
BSC	Balanced Scorecard
CAD	Computer-Aided Design
CIP	Continuous Improvement Process
CMMI	Capability Maturity Model Integration
CMMI DEV	Capability Maturity Model Integration Development
EC	Engineering Change
ERP	Enterprise Resource Planning
R&D	Research & Development
KPI	Key Performance Indicator
MES	Manufacturing Execution Systems
PDM	Product data management
PIPE	Process Indicators for Product Engineering
PLM	Product Lifecycle Management
ROI	Return on Investment
RQM	Requirements Management
TQM	Total Quality Management
TtM	Time-to-Market
VDMA	Verband Deutscher Maschinen- und Anlagenbau

References

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[1] VDMA. Process Indicators for Product Engineering (PIPE): Engineering Prozesse einheitlich bewerten. VDMA Verlag, 2013.

[2] Michael Nippa and Fabio Labriola. Roadmapping als integrative Planungsmethode im Rahmen eines situationsgerechten Time-to-Market Management. Technologie-Roadmapping. Springer, Berlin, Heidelberg, 2008.

[3] Klaus Ehrlenspiel and Harald Meerkamm. Integrierte Produktentwicklung: Denkabläufe, Methodeneinsatz, Zusammenarbeit. Carl Hanser Verlag GmbH Co KG, 2013.

[4] Peter R. Preißler. Betriebswirtschaftliche Kennzahlen: Formeln, Aussagekraft, Sollwerte, Ermittlungsintervalle. Walter de Gruyter, 2010.

[5] Nicole Zeise (2010): Modellierung von Kennzahlensystemen mit BPMN. In: Lecture Notes in Informatics (LNI)-Proceedings - Series of the Gesellschaft für Informatik (GI) Volume P-160/63. ISBN 978-3-88579-254-3.

[6] CMMI Institute. CMMI. Available at: https://www.cmmiinstitute.com/cmmi [Accessed: 12.07.2018].

[7] Wirtschaftslexikon24. Du Pont Kennzahlensystem. ROI. Available at: http://www.wirtschaftslexikon24.com/d/du-pont-kennzahlensystem/du-pont-kennzahlensystem.htm [Accessed: 16.07.2018].

[8] Robert S. Kaplan and David P. Norton. Balanced Scorecard-Strategien erfolgreich umsetzen. 1st edition, Schäffer-Poeschel, 1997.

[9] European Foundation of Quality Management. EFQM. Available at: http://www.efqm.org/ [Accessed: 16.07.2018].

[10] it-production. Wechselwirkungen von ERP- und MES-Kennzahlen - Stellschrauben für die Wertschöpfungskette. Available at: https://www.it-production.com/allgemein/wechselwirkungen-von-erp-und-mes-kennzahlenstellschrauben-fuer-die-wertschoepfungskette/ [Accessed: 16.07.2018].